A SunCam online continuing education course

Program Management for Engineering Projects

by

Mark Ludwigson, PE, PMP

Program Management for Engineering Projects
A SunCam online continuing education course

Course Outline:

Examination

Portfolio vs Program vs Project

Many organizations manage a portfolio of multiple projects. Projects that are closely related can be grouped together to form a "program". The management of such programs can have a big impact on achieving important goals for an organization.

The following definitions help distinguish between portfolios, programs, and projects:

Portfolio management = Oversight of multiple projects and programs

Program management = Oversight of multiple related projects with overlapping schedules and common objectives

Project management = Management of a single project with specific objectives

Example Portfolio

Figure 1 shows an example of a production company with a portfolio of projects and two programs. The first program is to expand facilities to allow for the production of a new item called Product C. There are currently two facilities to be upgraded: Plant 1 and Plant 2. Thus, the Product C program has two projects, one for Plant 1 and one for Plant 2. If an additional facility upgrade is needed in the future, a third project would be added to the Product C program.

The second program is for changes needed in the production of Product B, both to increase production efficiency and to make the product more appealing to a new target audience. There are two projects for this program.

The last project is for an upgrade to the standby generator at Plant 1. Since there are no related projects, it is not considered part of a program. If the company had an initiative to assess and upgrade several standby generators, then together those projects could be considered a program.

A standalone improvement project that is broken into multiple stages (study, preliminary design, final design, bidding, construction) is NOT considered a program.

Note that each program is assigned a number, and the projects within that program have a related number. This makes document management easier.

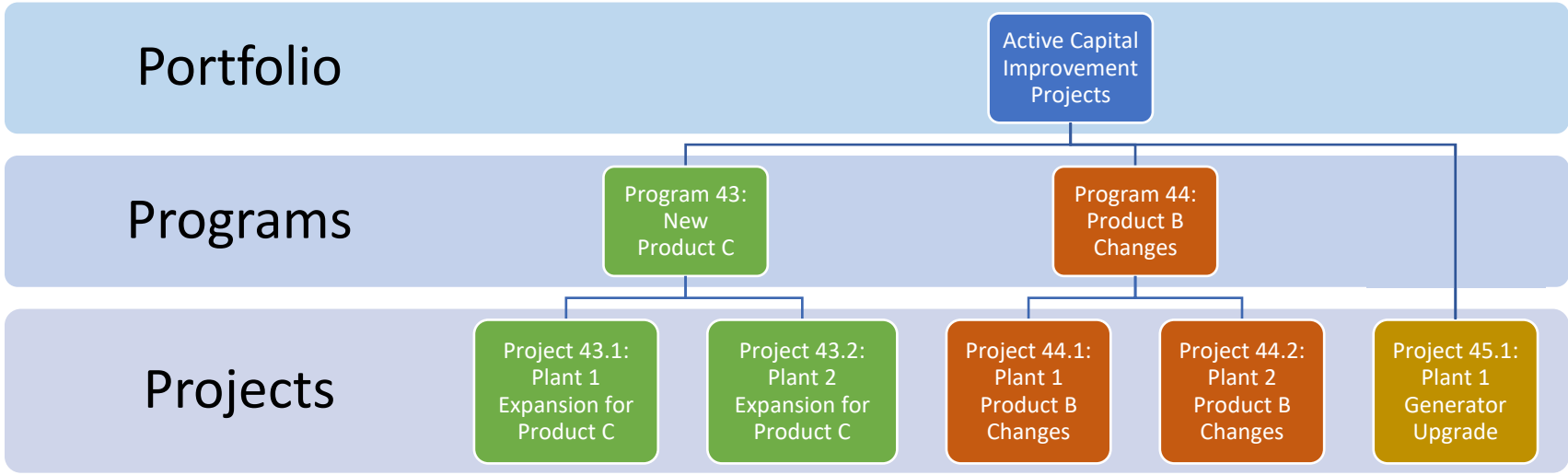


Figure 1: Depiction of a company with a portfolio of capital improvement (CIP) projects.
The program in green has projects related to production of a new Product C.
The program in red has projects related to revisions needed for the production of Product B.
The project in orange is unrelated to all other active projects and so is not part of a program.
Source: Author

Titles and Roles

Program management (also called program administration) is performed by a *program manager*. Other titles include *program administrator* or *program director*. Sometimes a *project manager* is assigned to oversee multiple related projects but never given a special title other than *project manager*. So many project managers perform program management duties from time to time.

For companies that manufacture products, a *product manager* is often assigned to one or more product lines. The *product manager* will provide input and oversight over all improvement projects for a product line. The collection of projects for a product line can be considered a program, and thus the product manager often performs program management tasks. In smaller organizations, there may not be a separate program manager, and the project managers report to the product manager for projects related to the product.

In consulting firms, a *client services manager* will perform some program management duties, such as ensuring that consistent services are provided and lessons learned are applied across multiple projects for the same client. Managing a group of projects for a client has many similarities to managing a program.

Figure 2: Example nameplate for a program manager

Source: www.hsfgiftshop.com/product-p/1264fema.htm

Staff Organization

See Figures 3 for a staff organization chart for a program with three project managers to manage the various projects within the program. Note that sometimes the program manager will also assume the role of project manager on one or more smaller projects. The director is at the portfolio level and may have multiple program managers as subordinates. Also, sometimes a program manager will manage multiple programs.

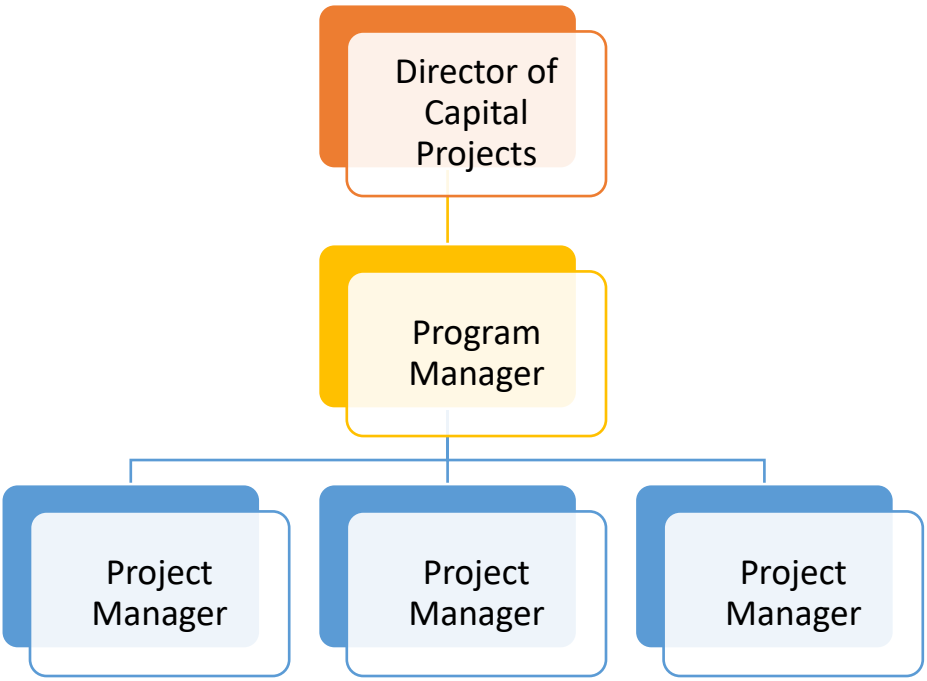


Figure 3: Example Staff Organization Chart for a program
Source: Author

RACI Matrix

A RACI (Responsible, Accountable, Consulted, Informed) matrix helps clarify roles and responsibilities for tasks within a program or project.

Role Definitions:

- R = Responsible = The “doer” who performs the task or activity.
- A = Accountable = Answerable for the successful completion of the task. Has authority to approve tasks and confirm complete.
- C = Consulted = Provides input or expertise to help complete a task.
- I = Informed = To be updated on a task's progress but not directly involved.

See Table 1 for an example RACI matrix for program.

Authority

The program sponsor is often the person in authority that secures funding and approves changes. For consultancy work, this may be a director in the client’s organization. For internal programs, the program sponsor may be a company executive, vice president, or director.

Additionally, there may be a steering committee and advisory committee to provide oversight of a program, including approving the initial business case, program charter, management plan, and any program changes.

Table 1: Example RACI Matrix for a Program									
Phase	Activity or Deliverable	Program Sponsor	Portfolio Director	Program Manager	Project Managers	Technical Team	Buyer	Constr. Contractors	Operations Staff
Definition	Business Case	R/A	C	C					
	New Program Request	A	C	R					
	Baseline Schedule	A	C	R	C				
	Baseline Budget	A	C	R	C				
	Program Plan	I	C	R/A	C				I
Delivery	Project Plans	I	I	A	R	C	I		I
	Drawings			I	A	R			C
	Specifications			I	A	R			C
	Securing Permits			I	A	R			
	Equipment Purchases			I	A	C	R	I	
	Bidding			I	A	C	R	I	
	Construction			I	A			R	
	Inspections			I	A	R		I	C
	Commissioning	I		I	A	R		R	I
	New Systems Operations	I	I	I	I	I		I	R/A
	Project Changes	C	I	A	R	C	I	I	I
	Program Changes	A	I	R	C				I
	Project Lessons Learned	I	I	A	R	C	C	C	C
Closure	Program Lessons Learned	I	A	R	C				C
	Program closeout	A	I	R	I				I

PgMP Certification

Project managers often obtain Project Management Professional (PMP®) certification from the Project Management Institute, Inc. (PMI). Similarly, a Program Management Professional (PgMP®) certification can be obtained for practicing program management.

In order to obtain PgMP certification, a candidate must meet education and experience requirements, submit an application, pay a fee, and pass a 4-hour exam. The exam has 170 questions in the following categories:

- Strategic Program Alignment
- Program Life Cycle Management
- Business Alignment
- Stakeholder Engagement
- Governance

Maintaining PgMP certification requirements renewal every three years, including submitting documentation for a minimum of 60 professional development units (PDUs). PDUs can be obtained by learning, teaching others, presenting, reading, volunteering, and creating content.

The following two PMI documents are the guidance documents for PgMP certification:

1. *The Standard for Program Management*
    - Main topics:
        - Program Management Principles
        - Program Management Performance Domains
        - Program Activities
        - Program Tools and Techniques

2. *A Guide to the Project Management Body of Knowledge (PMBOK® Guide)*
    - Main topics:
        - System for Value Delivery
        - Project Management Principles
        - Project Performance Domains
        - Tailoring
        - Models, Methods, and Artifacts

Program Principles

The Standard for Program Management describes eight program management principles, as depicted in Figure 4. These principles are foundational attitudes and approaches that guide all aspects of a program. The program manager should embody these principles and live them out each day.

Typically, an organization will apply the same principles across all programs in a portfolio.

Figure 4: Program management principles per *The Standard for Program Management*.
Principles in **purple** are specific to program management.
Principles in **blue** are common with project management.
Source: Author

Program Performance Domains

The Standard for Program Management describes six performance domains, as depicted in Figure 5. Performance domains are the areas of activities that help achieve program goals. Domains are ways to put principles into action.

Typically, an organization will require all programs to apply the same performance domains. However, unique performance domains can be defined based on the goals of the program.

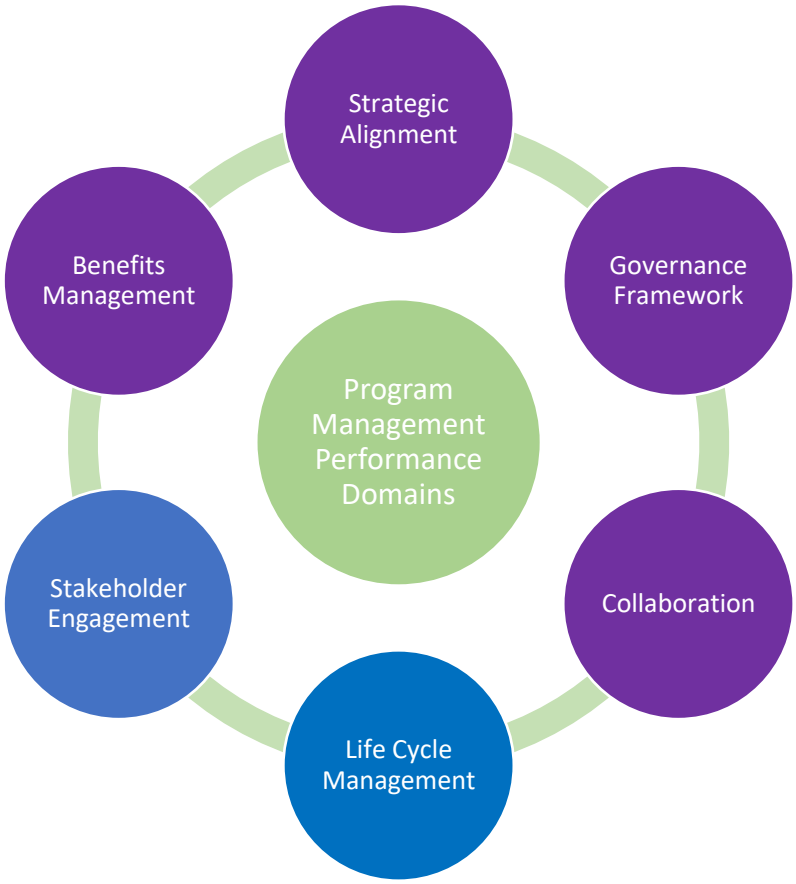


Figure 5: Program management performance domains per *The Standard for Program Management*.
Domains in purple are specific to program management.
Domains in blue are common with project management.
Source: Author

Table 2 compares Principles and Performance Domains per the various PMI standards. The values in **blue** are common to both program and project management. The values in **purple** are unique to program management.

Table 2: Comparing Principles and Performance Domains per PMI Standards

Principles		Performance Domains	
Project Management	Program Management	Project Management	Program Management
Change	**Change**	Stakeholders	**Stakeholder Engagement**
Leadership	**Leadership**	Development Approach & Life Cycle	**Life Cycle Management**
Risk	**Risk**	Team	**Strategic Alignment**
Stakeholders	**Stakeholders**	Planning	**Benefits Management**
Systems Thinking	**Benefits Realization**	Project Work	**Collaboration**
Tailoring	**Synergy**	Delivery	**Governance Framework**
Team	**Team of Teams**	Measurement	
Quality	**Governance**	Uncertainty	
Complexity			
Value			
Adaptability and Resiliency			
Stewardship			

Performance Criteria

Program managers are held responsible for achieving program performance criteria, which typically include the following:

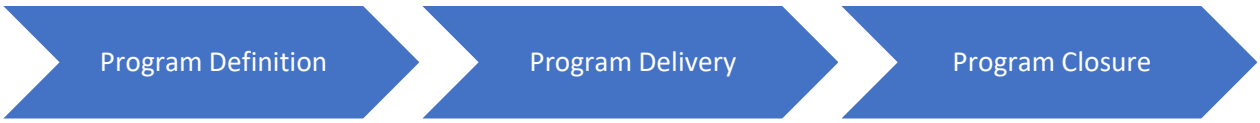
- Realizing intended benefits of program
- High quality installations
- Within schedule
- Within budget
- Low risk exposure
- External stakeholder satisfaction
- Internal stakeholder satisfaction

The advice provided in this course aims to achieve these and other performance criteria.

Often high-quality results are expected in a short time period and at a reasonable cost. There is an old saying that you can only pick two of three: quality, speed, or cost. But the reality is that all three are expected on most programs, with specific goals defined for each. Careful program management is the key to achieving the trifecta: quality work, on time, and within budget.

Phases of a Program

A program life cycle usually consists of three phases:



Some capital improvement programs are ongoing with no foreseen closure phase, as explained in the last section of this course. And some programs have more iterative lifecycles than the below described linear phases.

Program Definition

In this opening phase, the idea of a program is developed into a clear game plan which is presented to key stakeholders and authorization to proceed is obtained. The following documents are often prepared at this stage:

- Program definition
- Program business case
- Program charter
- Program roadmap
- Program risk assessment
- Program cost estimate
- Program management plan

The program management plan (aka program plan) ties together all the documents and provides a path forward. The next section focuses on creating a program plan.

Program Delivery

The program delivery phase is about executing projects and other components of the program. The completion of each project results in a benefit to the organization. Therefore, this phase is often referred to as the “benefits delivery” or “benefits realization” phase.

Projects are often referred to as “components” of a program. Components also include minor activities or tasks needed for the program that aren’t part of a single project and aren’t assigned a project number in the organization.

The program delivery phase involves heavy oversight and involvement in projects. Having projects fail is the common cause of program failures. Therefore, the program manager should carefully monitor projects and play an active role in helping each project succeed. This includes making sure the result of the project actually helps achieve the goals of the program.

Example Scenario A:

Program Manager Caitlin is in charge of a program aiming to replace all air compressors at three facilities in order to reduce downtimes due to frequent maintenance issues and increase operations efficiency. The program consists of three projects, one for each facility.

Figure 6: Example air compressor package.
Source: en.wikipedia.org/wiki/File:IngersollRand_R-series-R110.jpg

Caitlin decides to meet with potential air compressor suppliers, evaluate them, and select a supplier to proceed. She decides to treat these activities as a component of the program rather than creating a fourth project. The organization requires creating a project only if expenses total over $20,000 or labor is over 80 hours.

Caitlin reminds the three project managers that the new air compressors are to be fully functional, including controls integration, to achieve the goals of the program. The facilities recently upgraded to Ethernet controls communication and all new equipment (including the new air compressors) is to utilize Ethernet for controls and alarm signals.

A project manager reported that this was not part of the original scope of work and the air compressor supplier refused to entertain the requested changes. The project manager planned to complete the project with the previous agreed controls wiring and let operations staff deal with it. Caitlin knows this could undermine the goals of the program so she reviews the contract with the company's legal team and determines that the order can be cancelled if the supplier does not offer a solution.

Caitlin contacts the supplier and informs them of this in writing. The supplier changes their position and provides a cost proposal for including Ethernet communication, which is negotiated and accepted. This kept the program on track to increase operations efficiency.

Program Closure

The closure phase puts an end to the program. Before beginning closure procedures, it is important to confirm the benefits of the program have been realized. Typically, there is an extended period of time to confirm the new systems and structures are operating as intended.

At minimum, a program should remain open through the commissioning period (testing, startup, monitoring, and reporting) which can range from 1 to 6 months. A program can also stay open through the typical 12-month warranty period, since there are likely to be issues that require warranty coordination with contractors or suppliers. If the installation has been turned over to operations for beneficial use and the construction project(s) has been closed, the proceeding warranty period can be considered part of the program closure phase.

Tasks to close a project include:

- Confirm stakeholders agree on closing the program
- Inform team of intention to close the project
- Confirm all projects have been closed and staff cannot charge time
- Confirm all vendor invoices have been paid and signed lien waivers received
- Confirm final payments received from client, if applicable
- Refund any remaining budget, if applicable
- Archive project and program documents
- Organize and finalize lessons learned
- Document any remaining risks and inform/transfer to appropriate parties

Lessons Learned Log

The program manager is often the best person to gather and document lessons learned from the program. Typically, in the closure phase, a log is made that lists issues encountered and how they may be prevented on future projects. The goal is risk minimization for future programs and projects. Each project may have a lessons learned log which can be referenced or incorporated into the overall program lessons learned log. See Table 3 for an example.

Table 3: Example Lessons Learned Log for Program ACME

Lesson No.	Project No.	Work Element	Issue	Lesson
1	7604.1	Structural	Building permit comment: structural observations not listed on drawings	List any required structural observations on structural drawings
2	7604.1	Electrical	Multiple instruments missing from electrical drawings but shown on process drawings	Cross check instruments on process drawings with electrical drawings
3	7604.2	Civil	Duct bank encountered along utility route, not shown on drawings, redesign required	Perform utility locates along routes of proposed utilities
4	7604.4	Constr.	Contractor started work at 6am and neighbor complained; potential noise ordinance violation	Review noise ordinance and avoid construction work during quiet hours

Program Management Plan

A program management plan is a game plan for achieving victory with the program. It is sometimes called a program plan. The plan is a document that contains everything one needs to know in order to run the program. The plan specifies the program governance and explains how the various components of a program are to be managed cohesively. A program management plan has similarities to a project management plan (sometimes called a project plan). See Table 4 for a comparison, with unique elements in **purple**.

Table 4: Typical Plan Elements

Project Management Plan	Program Management Plan
Project Overview	**Program** Overview
Project Goals & Objectives	**Program** Goals & Objectives
Project Scope	**Program Components and Projects**
Work Breakdown Structure (WBS)	**Program Governance**
Schedule	Schedule **or Roadmap**
Budget	Budget
Resource Management	Resource Management
Risk Management	Risk Management
Communications Management	Communications Management
Stakeholder Management	Stakeholder Management
Change Management	Change Management
Quality Management	**Benefits Realization**
Project Closeout Procedure	**Program** Closeout Procedure

The following documents are often referenced or incorporated into a program management plan:

- Program business case
- Program charter
- Program roadmap or milestone list
- Program risk assessment
- Program cost estimate

Plan Updates

The program management plan should be updated as needed at any time during the program. Program changes are often needed due to internal and external influences.

Example internal influences:

- Company policy change
- Key program staff change
- Major error discovered
- Internal risk change
- Internal safety incident
- Major project delay due to design, permit or construction issue

Example external influences:

- Regulatory (permit) change
- External stakeholder change
- Major economy change
- External risks change
- Funding change
- Major weather or climate events
- Major project delay due to external event such as COVID outbreak

The following pages show an example table of contents for a program management plan.

Program Management for Engineering Projects
A SunCam online continuing education course

EXAMPLE PLAN

Contents

Baseline Schedule

The program baseline schedule is created in the Program Definition phase, added to the program management plan, and updated as needed throughout the program. It is a high-level schedule showing the program phases, major milestones, and major components/projects. See Figure 7 for a Gantt chart example.

Milestone List

Often a more basic roadmap or milestone list is created as part of the business case or program charter. The roadmap or milestone list is expanded with more detail in a baseline schedule. For a simple program, a milestone list may suffice to start the program. See Table 5 for an example Milestone List.

Table 5: Example Milestone List

ID	Phase	Milestone Description	Milestone Date	Status
1	Definition	Program Contract Executed	02/01/26	Complete
2	Definition	Program Management Plan Approved	03/01/26	Complete
3	Definition	Transition to Delivery Phase	04/01/26	Pending
4	Delivery	Project A Planning Starts	05/01/26	-
5	Delivery	Project A Construction Starts	11/01/26	-
6	Delivery	Project A Substantial Completion	09/01/27	-
7	Delivery	Project A Final Completion	11/01/27	-
8	Delivery	Project B Planning Starts	08/01/26	-
9	Delivery	Project B Construction Starts	01/01/27	-
10	Delivery	Project B Substantial Completion	10/01/27	-
11	Delivery	Project B Final Completion	12/01/27	-
12	Closure	Lessons Learned Log Issued	01/01/28	-
13	Closure	Program Closed	02/01/28	-

ID	Task Name	Duration	Start	Finish
1				
2	**Program ACME**	**825 days?**	**Mon 12/1/25**	**Fri 1/26/29**
3	Program Definition	65 days	Mon 12/1/25	Fri 2/27/26
4	Program Delivery	696 days	Mon 3/2/26	Mon 10/30/28
5	Program Closure	65 days	Mon 10/30/28	Fri 1/26/29
6	Program Complete	0 days	Fri 1/26/29	Fri 1/26/29
7				
8	**Project A**	**449 days**	**Mon 3/2/26**	**Thu 11/18/27**
9	Project A Start	0 days	Mon 3/2/26	Mon 3/2/26
10	Planning	45 days	Mon 3/2/26	Fri 5/1/26
14	Preliminary Design	42 days	Mon 5/4/26	Tue 6/30/26
22	Final Design	53 days	Wed 7/1/26	Fri 9/11/26
34	Regulatory Approvals	81 days	Wed 7/1/26	Wed 10/21/26
42	Equip. Procurement	190 days	Thu 10/22/26	Wed 7/14/27
52	Preconstruction	105 days	Thu 10/22/26	Wed 3/17/27
56	Construction	150 days	Thu 3/18/27	Wed 10/13/27
63	Commissioning	17 days	Thu 10/14/27	Fri 11/5/27
68	Project Closure	10 days	Fri 11/5/27	Thu 11/18/27
69	Project A Complete	0 days	Thu 11/18/27	Thu 11/18/27
70				
71	**Project B**	**474 days?**	**Mon 9/14/26**	**Thu 7/6/28**
72	Project B Start	0 days	Mon 9/14/26	Mon 9/14/26
73	Planning	45 days	Mon 9/14/26	Fri 11/13/26
77	Preliminary Design	42 days	Mon 11/16/26	Tue 1/12/27
85	Final Design	53 days	Wed 1/13/27	Fri 3/26/27
97	Regulatory Approvals	81 days	Wed 1/13/27	Wed 5/5/27
105	Preconstruction	105 days	Thu 5/6/27	Wed 9/29/27
109	Construction	175 days	Thu 9/30/27	Wed 5/31/28
116	Commissioning	17 days	Thu 6/1/28	Fri 6/23/28
121	Project Closure	10 days	Fri 6/23/28	Thu 7/6/28
122	Project B Complete	0 days	Thu 7/6/28	Thu 7/6/28
123				
124	**Final Delivery**	**90 days**	**Mon 6/26/28**	**Mon 10/30/28**
125	Operations Review	30 days	Mon 6/26/28	Fri 8/4/28
126	Final Punchlist Items	30 days	Mon 8/7/28	Fri 9/15/28
127	Float	30 days	Mon 9/18/28	Fri 10/27/28
128	Improv. Complete	0 days	Mon 10/30/28	Mon 10/30/28

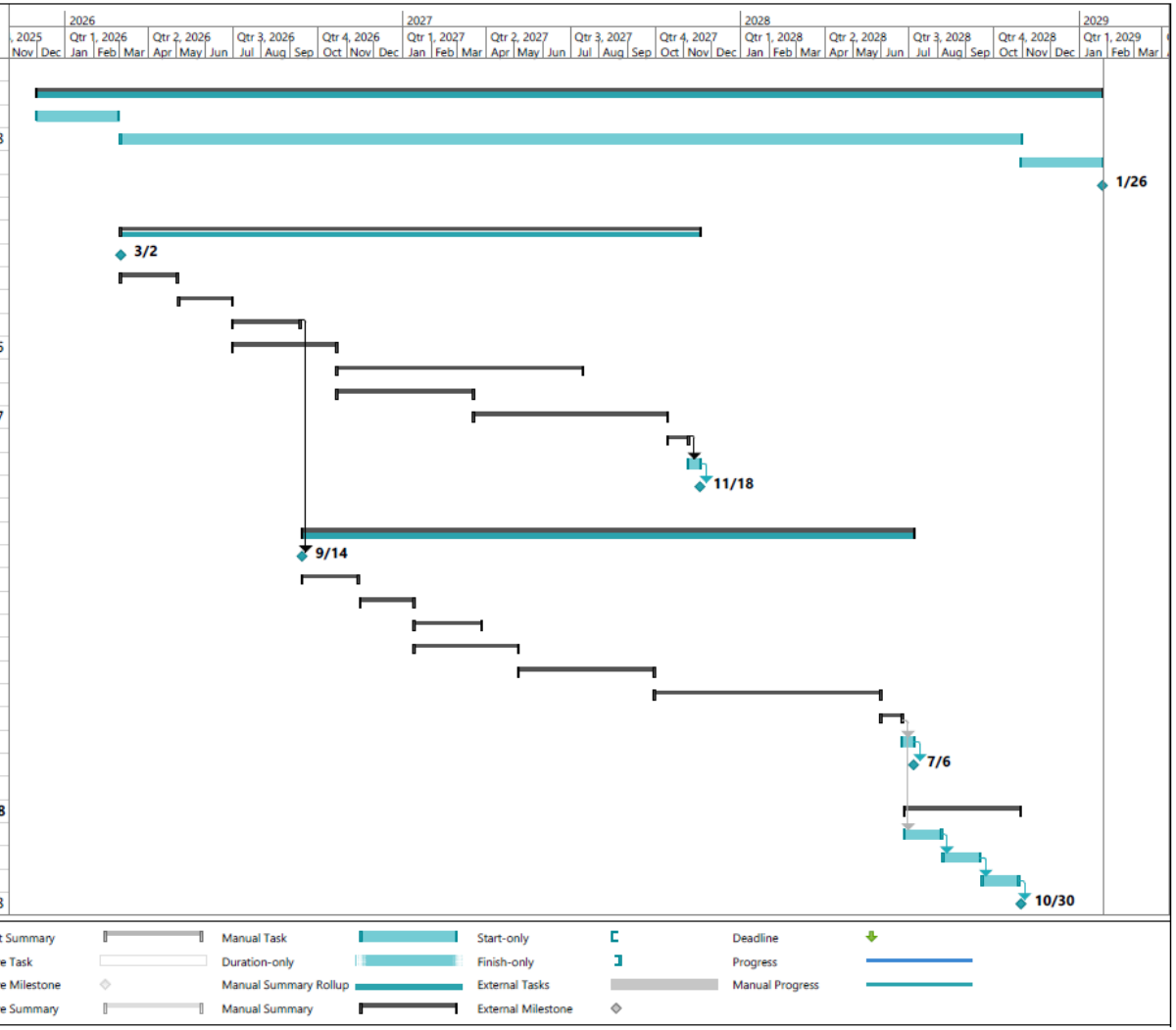


Figure 7: Example baseline schedule in Gantt format, for a program with two projects (author).

Creating a Baseline Schedule

Here are steps to develop a baseline schedule:

1. Review business case, charter, roadmap and/or milestone list
2. Select software to utilize (Excel, MS Project, MS Planner, Primavera P6, Smartsheet, Monday, Procore, etc.)
3. Add Definition Phase and estimate duration
    a. Optional: Add tasks such as creating program management plan
4. Add Delivery Phase
    a. Add each component/project
    b. Estimate component durations
    c. Show important interdependencies/predecessors (for example, not being able to start the second project until the first project is complete)
    d. Include milestones (0 day activities) for major events such as projects starting and ending
    e. Optional: Add major tasks within each project
    f. Allocate float/contingency to account for unknowns
5. Add Definition Phase and estimate duration
    a. Optional: Add tasks such as developing lessons learned
6. Identify the critical path and highlight it red
7. Optional: Assign resources responsible for each activity in a separate column

Contingency

There are several options for adding contingency (extra time for unknowns) to a baseline schedule:

- Include a contingency activity at the end of each Phase.
- Assign small amounts of contingency time after each activity.
- Add extra time to specific activities with unknowns or high risk of delay.

Float

Float applies to activities that are not on the critical path. Float (also called slack) is the time such activities can be delayed without impacting the critical path.

In the schedule, each activity can have an early finish date (no float utilized) and a late finish date (all float utilized). These are separate columns. This makes clear how long an activity can be delayed without an impact on the overall schedule. This approach is common for a construction schedule.

Schedule Tracking

Managing a program means being responsible for components being completed **on time**. This is primarily done by comparing the current progress to the baseline schedule (revised for any agreed changes) and by focusing the team on critical path tasks.

Progress Schedules

The project schedule should be periodically reviewed to visually understand if work is progressing ahead or behind schedule. A vertical line is drawn for the current date. Activities to the left of the line should be completed.

The schedule can be revised as a “progress schedule” or “current schedule”. Activity durations and start dates can be adjusted based on the actual work completed and the latest projections for future work. Additional tasks and schedule details can be added as the program progresses. The original “Baseline Schedule” should be saved as “read only” as used for reporting progress and defining changes.

Percent Complete Evaluation

A percent complete evaluation helps determine if a scheduled activity is ahead or behind schedule. This is done by comparing the “scheduled percent complete” to the “actual percent complete”, as depicted in Figure 8. The difference is the amount ahead or behind schedule, in percent, which can be converted to days by multiplying by the task duration. Often the actual task duration differs from the baseline assumption, which is accounted for in a percent complete evaluation.

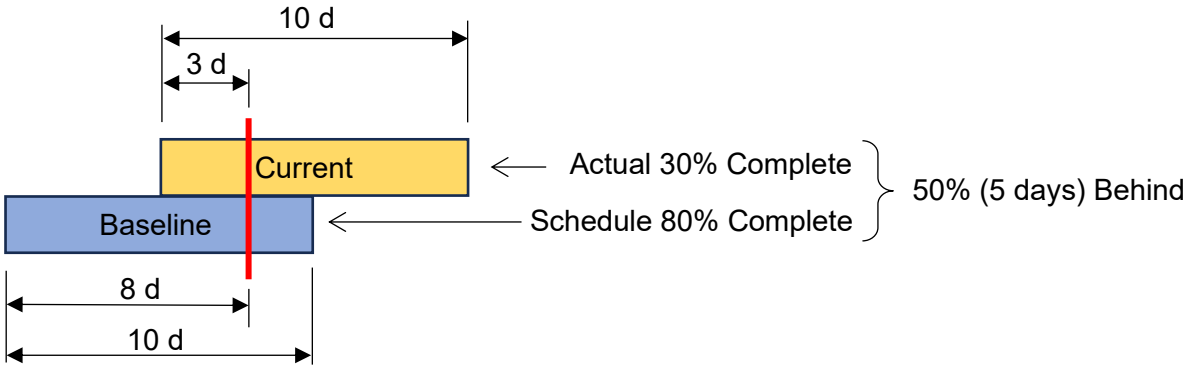


Figure 8: Percent complete comparison for an activity that is behind schedule.
Source: Author

The project manager should regularly do a percent complete evaluation for tasks within their project, with results reported to the program manager. This information is used by the program manager to do a percent complete evaluation for the overall program.

Table 6 is an example percent complete status table for a program. Six of eighteen tasks are complete, two are behind, one is on track, and one is ahead of schedule. It is concerning that there are more tasks behind than ahead of schedule. However, in terms of critical path items, there are no tasks behind, and one item ahead, so overall the project is ahead of schedule. The float for the two items behind schedule should be reviewed to confirm they are not being delayed to the point of becoming on the critical path.

Table 6: Example Percent Complete Status for a Program

Phase	Major Tasks	Critical Path	Percent Complete		Status
			Baseline	Actual	
Definition	Program Contract Executed	Y	100%	100%	Done
	Program Management Plan Approved	Y	100%	100%	Done
	Transition to Delivery Phase	Y	100%	100%	Done
Delivery	Project A Design	Y	100%	100%	Done
	Project A Bidding	N	100%	80%	Behind
	Project A Construction	N	20%	0%	Behind
	Project A Commissioning	N	0%	0%	-
	Project B Design	N	100%	100%	Done
	Project B Bidding	N	60%	60%	On track
	Project B Construction	N	0%	0%	-
	Project B Commissioning	N	0%	0%	-
	Project C Design	Y	100%	100%	Done
	Project C Bidding	Y	0%	20%	Ahead
	Project C Construction	Y	0%	0%	-
	Project C Commissioning	Y	0%	0%	-
	Operations Assessment	Y	0%	0%	-
Closure	Lessons Learned Log Issued	Y	0%	0%	-
	Program Closed	Y	0%	0%	-

Determining percent completes is a step towards an earned value analysis, which considers both the schedule and budget status, as explained later in this course.

Lifecycle Costs

Lifecycle cost (LCC) refers to the total cost of ownership over the life of an asset, including maintenance, energy usage, operation labor, chemical use, waste disposal, and demolition. Many capital improvement programs and projects add systems and processes that require significant ongoing operations and maintenance costs which need to be taken into account. The full LCC is often considered when preparing a business case and making a program go/no-go decision.

For a program, LCC can be calculated as the sum of the lifecycle costs for the projects plus any other program costs (overhead and other components). Often a time period of 20 years is used for a lifecycle analysis.

Present Worth LCC

The lifecycle cost can be calculated using the present worth approach. The formula is as follows:

$$Lifecycle\ Cost = Capital\ Cost + Annual\ O\&M * PWF - Salvage\ Value$$

where: $Annual\ O\&M = annual\ operations\ and\ maintenance\ costs$

$$PWF = Present\ Worth\ Factor = \frac{(1+i)^T - 1}{i*(1+i)^T}$$

$i = interest\ rate\ (or\ discount\ rate)$

$T = number\ of\ years$

Simplified LCC

Given the high variability in cost estimates at the business case stage, it is common to ignore PWF and salvage value, and use this simplified LCC formula:

$$Lifecycle\ Cost = Capital\ Cost + Annual\ O\&M * Years$$

The simplified LCC approach is also common if inflation is high or similar to interest rates, or if discount rates are low, since the present worth factor (PWF) will be similar to the “number of years”.

Consider O&M during Design

Smart decisions should be made early in the design process to minimize operations and maintenance (O&M) costs over the lifecycle of installation. As a project or program progresses, opportunities for reducing lifecycle cost diminish as the design becomes solidified. It is helpful to consider operations impacts early in the design process, such as during studies, alternatives comparisons, basis of design reports, and preliminary design. Input should be gained from operations staff.

Example Problem 1

Given the following, calculate the 20-year lifecycle cost with the simplified approach:

- Capital Cost = $8M
- Annual O&M = $100,000

Solution:

Using the simplified LCC formula:

$$Lifecycle\ Cost = Capital\ Cost + Annual\ O\&M * Years$$

$$\boldsymbol{Lifecycle\ Cost} = \$8{,}000{,}000 + \$100{,}000 * 20 = \$\mathbf{10{,}000{,}000}$$

Return on Investment

Return on Investment (ROI) is a measure of a program's profitability by comparing the anticipated profit to the program cost. ROI applies to programs that have profit or cost savings as a goal.

A common ROI formula for a program is as follows:

$$ROI = \left(\frac{Revenue - Program\ Cost}{Program\ Cost}\right) * 100 = \left(\frac{Net\ Profit}{Program\ Cost}\right) * 100$$

The above formula requires an assumption on the time period (number of years) for the revenue and doesn't include operations and maintenance costs. Therefore, the following ROI formula is more comprehensive and applicable to capital improvement programs.

$$ROI = \left(\frac{Annual\ Revenue * Years - Lifecycle\ Cost}{Lifecycle\ Cost}\right) * 100$$

Here, lifecycle cost is for the program, which is the sum of the lifecycle costs for the projects plus any other program costs (overhead and other components). See the previous section for more details on calculating lifecycle costs.

Some programs or projects provide cost savings instead of revenue/profit. For example, a new digester and biogas generator would produce electricity and heat which results in energy bill savings but not revenue. In such cases, the ROI formula is as follows:

$$ROI = \left(\frac{Annual\ Savings * Years - Lifecycle\ Cost}{Lifecycle\ Cost}\right) * 100$$

Anticipated ROI is often calculated as part of the business case to justify the program. Often a high and low range are calculated since the estimated cost and revenue are very rough at that stage. ROI should be updated whenever there are budget changes in the program or external influences that impact the anticipated revenue.

ROI can also be calculated for individual projects within a program, to help select projects that provide the best financial return.

Example Problem 2

A solar power upgrade program is estimated to save $200,000 a year in electricity costs. The program has three projects, each with a 20-year lifecycle cost of $500,000, plus a program overhead of $100,000. What is the ROI for a 20-year period?

Solution:

Use the following ROI formula:

$$ROI = \left(\frac{Annual\ Savings * Years - Lifecycle\ Cost}{Lifecycle\ Cost}\right) * 100$$

$$Annual\ Savings = \$200{,}000/yr$$

$$Years = 20\ yr$$

$$Lifecycle\ cost = \sum Lifecycle\ cost_{projects} + Program\ overhead$$

$$Lifecycle\ cost = \$500{,}000 * 3 + \$100{,}000 = \$1{,}600{,}000$$

$$\boldsymbol{ROI} = \left(\frac{\frac{\$200{,}000}{yr} * 20\ yr - \$1{,}600{,}000}{\$1{,}600{,}000}\right) * 100 = \left(\frac{\$2{,}400{,}000}{\$1{,}600{,}000}\right) * 100 = \mathbf{150}\%$$

Payback Period

The payback period is the time it takes for a program to recover its capital cost and start to generate a net profit or net savings. The following is a common formula for a capital improvement program:

$$Payback\ Period = \frac{Program\ Cost}{Annual\ Revenue - Annual\ Costs}$$

Or, if a project results in savings instead of profit:

$$Payback\ Period = \frac{Program\ Cost}{Annual\ Savings - Annual\ Costs}$$

Example Problem 3
What is the payback period for a program with the following:

- Program Cost = $2,000,000
- Annual O&M Costs = $50,000
- Annual Savings = $300,000

Solution:
The following formula is used:

$$\boldsymbol{Payback\ Period} = \frac{Program\ Cost}{Annual\ Savings - Annual\ O\&M\ Costs}$$

$$= \frac{\$2{,}000{,}000}{\$300{,}000 - \$50{,}000} = \boldsymbol{8\ years}$$

Cash Flow Projection

A cash flow projection estimates a program's financial change per time periods (month, quarter, or year). It is also called projected spending. See Table 7 for an example for a three-year long program with quarterly totals. The excel file is also provided as software included with the course.

Programs typically last many years, so the costs are spread over multiple years. An organization needs to be prepared so there are funds available to pay program expenses. To address this, cash flow projections are performed during the Program Definition phase. Careful scheduling and detailed spending projections can help prevent a shortage of funding and associated delays.

The following steps can be used to create a cash flow projection:

1. Review program roadmap, baseline schedule, and cost estimates
2. Decide on a time period (years, quarters, months, weeks, etc.)
3. Create a table with the following:
    a. Rows for projects and other program components
    b. Column with total cost for each component
    c. Columns for each time period, covering the entire program period
    d. Row at bottom with total costs for each time period
    e. Row at bottom with total costs for each year
4. For each component, breakdown estimated costs by time period
    a. If breakdown is unknown, put equal amounts for each time period with the sum equaling the component total; make note to revise in future
    b. Add contingency costs if not already in cost estimates
    c. Optional: add color coding for stages within each project
5. Add the estimated costs for each quarter and each year for bottom rows
    a. These totals can be rounded up to form the program budgets, which is the maximum spending per time period
    b. Confirm total program budget aligns with business case or other documents; discuss any difference with program sponsor as needed

Cash flow projections should be updated regularly to confirm projections are accurate.

Table 7: Example Program Cash Flow Projection
(coloring: design, bid, construction, other)

Comp. No.	Component/ Project Name	Cost Estimate / Budget	2026				2027				2028			
			Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1	Program Overhead	$360,000	$30,000	$30,000	$30,000	$30,000	$30,000	$30,000	$30,000	$30,000	$30,000	$30,000	$30,000	$30,000
2	Facility A Upgrade	$1,220,000	-	$100,000	$100,000	$10,000	$10,000	$100,000	$200,000	$300,000	$300,000	$100,000	-	-
3	Facility B Upgrade	$820,000	-	$50,000	$50,000	$10,000	$10,000	$100,000	$300,000	$200,000	$100,000	-	-	-
4	New Facility C	$2,120,000	-	$50,000	$150,000	$10,000	$10,000	$300,000	$300,000	$600,000	$600,000	$100,000	-	-
5	Facility D Upgrade	$750,000	-	$100,000	$100,000	$10,000	$10,000	$100,000	$30,000	$300,000	$100,000	-	-	-
6	Operations Assessment	$100,000	-	-	-	-	-	-	-	-	-	$50,000	$50,000	-
Quarter Total		$5,370,000	$30,000	$330,000	$430,000	$70,000	$70,000	$630,000	$860,000	$1,430,000	$1,130,000	$280,000	$80,000	$30,000
Annual Total			$860,000				$2,990,000				$1,520,000			

Example Problem 4

Program Manager Susan submitted the cash flow projection in Table 7 to the portfolio director. He said the department budget can't support program spending of more than $1.2M in any quarter. Which single project can Susan delay by a quarter to comply with the spending cap?

Solution:

Susan identifies that the only quarter with spending more than $1.2M is 2027 Q4 with $1.43M, which has an excess of $230,000. Although any of the projects could be shifted to reduce the total, only components 5 and 6 would reduce the 2027 Q4 total by more than $230,000.

Delaying Component 6 (Facility D Upgrade) to start 2026 Q3 would increase the 2028 Q1 total to over $1.2M, so this is not acceptable.

Delaying Component 5 (New Facility C) to start 2026 Q3 would decrease the 2027 Q4 total to $1.13M, and not change 2028 Q1, so this is the solution. Susan adjusts the cash flow projection and resubmits it to the director.

Budget Tracking

Being responsible for design means being responsible for staying within the agreed budget. Budget management involves these main tasks:

- Review financial drivers for the program (ROI, payback period, etc.)
- Creating a baseline budget (in conjunction with a baseline schedule) and cash flow projection
- Assigning budgets to program components/projects
- Reviewing budgets with project managers and gaining commitments
- Identifying budget risks and creating mitigation plans
- Regularly assess the budget status
- Recover from cost overruns by enacting mitigation plans

Earned Value

The current budget status can be determined by the “earned value” approach. Earned value is the initial budget value of the work completed to date. If spending (actual cost) is greater than the earned value, the program is overbudget. If spending is less than the earned value, the program is under budget. The earned value assessment can be applied to individual projects and the overall program. First step is to review spending to date and determine the percent completes for program components.

Example Problem 5

Continuing with Example Problem 4, after five quarters, Susan wants to assess the program budget status using excel.

Solution:

Susan creates the excel sheet shown in Figure 9 (software included with this course). She inputs data in the green "% Complete" column, which when multiplied by the budget gives the "Earned to Date" values. She then inputs the green "Spent to Date" fields. The difference between the two is the amount over or under budget.

Program No. 26-0120

Program Manager: Jenny Acme

Assessment Date:	1/10/2027		
Overall Budget Status:	OVER	$7,000	1%

	PM	INITIAL BUDGET	% COMPLETE	EARNED TO DATE	SPENT TO DATE	% SPENT	BUDGET STATUS	AMOUNT OVER (UNDER)	% OVER (UNDER)
Definition Phase			INPUT		INPUT				
Overhead	Jenny	$ 30,000	100%	$ 30,000	$ 25,000	83%	UNDER	$ (5,000)	-17%
Delivery Phase									
Program Overhead	Jenny	$ 300,000	30%	$ 90,000	$ 75,000	25%	UNDER	$ (15,000)	-17%
Facility A Upgrade	Jenny	$1,220,000	20%	$ 244,000	$ 250,000	20%	OVER	$ 6,000	2%
Facility B Upgrade	Howard	$ 820,000	25%	$ 205,000	$ 200,000	24%	UNDER	$ (5,000)	-2%
New Facility C	Mary	$2,120,000	20%	$ 424,000	$ 450,000	21%	OVER	$ 26,000	6%
Facility D Upgrade	Howard	$ 750,000	10%	$ 75,000	$ 75,000	10%	ON BUDGET	$ -	0%
Operations Assessment	Jenny	$ 100,000		$ -	$ -	0%	N/A	$ -	#DIV/0!
Closure Phase									
Overhead	Jenny	$ 30,000		$ -	$ -	0%	N/A	$ -	#DIV/0!
TOTALS									
Total to Date		$5,370,000	20%	$ 1,068,000	$ 1,075,000	20%	OVER	$ 7,000	1%

Figure 9: Budget assessment table for Example Problems 5 and 6.
Source: Author

Example Problem 6

Continuing with Example Problem 5 and using the data in Figure 9, how much is the program over or under budget? Which projects are over budget?

Solution:

In Figure 9, the sums at the bottom represent the overall project "Earned to Date" of $1,068,000 and "Spent to Date" of $1,075,000, for a difference of $7,000. Since spent is more than earned, the project is $7,000 over budget. This is 1% over, which is a relatively small overage.

The following projects are over budget:

- Facility A Upgrade
- New Facility C

S-Curve

For both the overall program and individual projects, the total “Earned to Date” and “Spent to Date” values can be recorded on a regular basis, typically once a month, and then plotted along with the original budget values to form what is called an “S-Curve”. Time is the X-axis and the budget/spent is the Y-axis (in dollars or percent). See Figure 10 for an example.

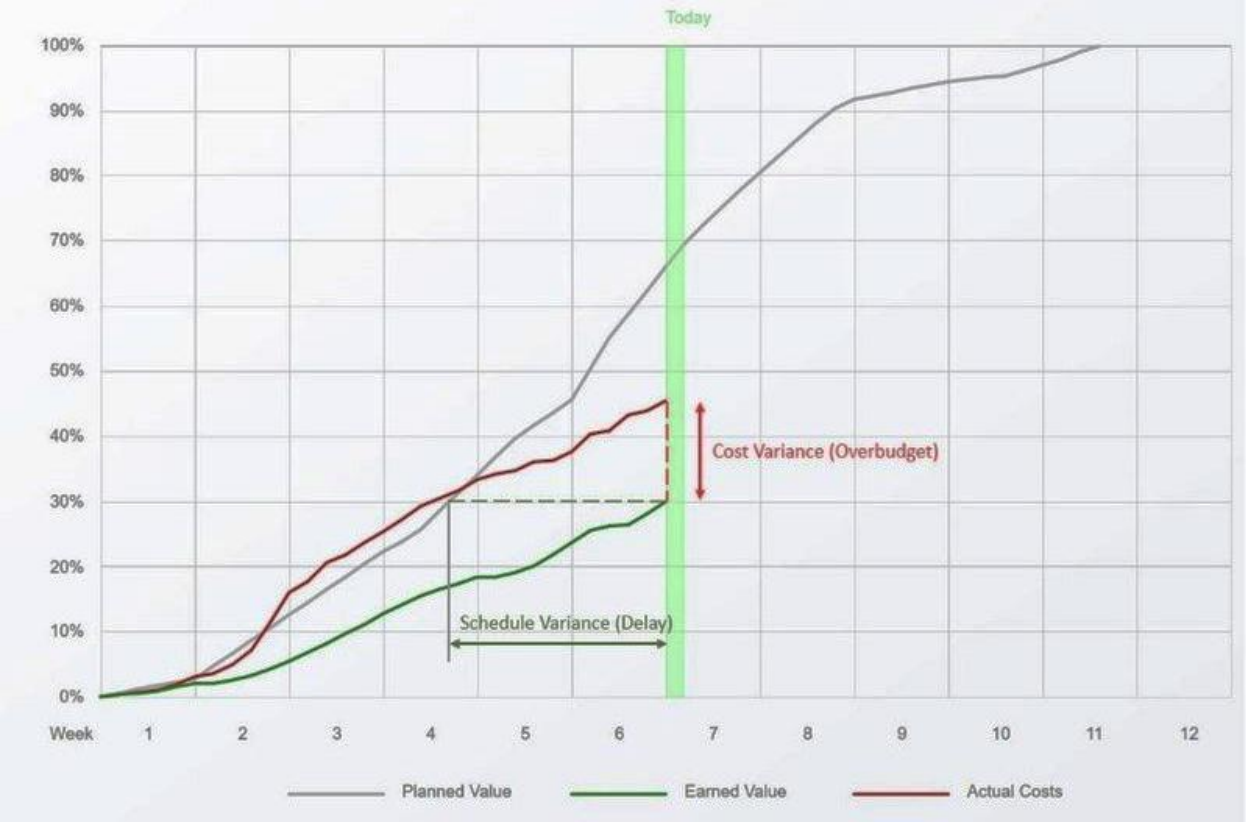


Figure 10: Earned value “S-Curve” for a project that is overbudget and delayed based on total spent (actual cost) and earned value at the end of week 6 of 12. The gray “Planned Value” line represents spending according to the baseline schedule and budget.

Source: commons.wikimedia.org/wiki/File:EarnedValueChartNormalized.jpg, Kokcharov, CC-BY-SA-4.0

It is called an S-Curve because spending is usually greatest in the middle period of the project which makes the curve steeper in the middle and ends up shaped like a stretched-out letter “S”.

Earned Value Parameters

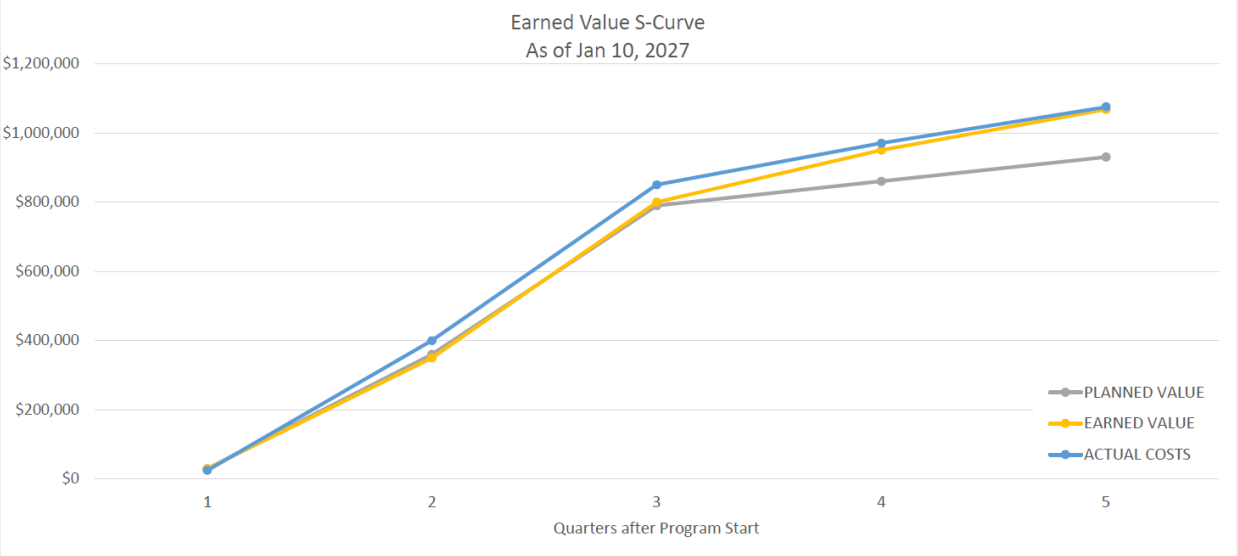
Earned value data can be used to calculate other parameters to assess the state of the program or individual projects. The goal is to help direct actions that keep the project within schedule and budget and minimize any slippage. Common parameter formulas are in Table 8.

Table 8: Earned Value Parameters

Parameter	Abbr.	Formula
Total Budget	TB	from Contract
Activity Budget	AB	from budget breakdown
Planned Value (Baseline Budget to Date)	PV	∑ AB (to Date)
Actual Cost (Spent to Date)	AC	from accounting
Earned Value (Earned to Date)	EV	∑ AB x % Complete
Cost Variance (Budget Status)	CV	CV = EV – AC (negative is over budget)
Schedule Variance (Schedule Status)	SV	SV = EV – PV (negative is behind)
Cost Performance Index	CPI	CPI = EV/AC
Schedule Performance Index	SPI	SPI = EV/PV
Estimated Cost at Completion	EAC	EAC = TB + CV

Example Problem 7

Continuing with Example Problem 6, Susan tabulates the planned value, earned value, and actual costs and plots it in the below figure (included with course software).



Given the following, help Susan determine the schedule variance and cost variance.

- Planned Value $930,000
- Earned Value $1,068,000
- Actual Costs $1,075,000

Is the project ahead of schedule?

Solution:
Based on the values above and formulas in Table 8:

- Schedule variance (SV) = EV – PV = $1,068,000 - $930,000 = $138,000
  SV is positive so project is ahead of schedule.

Budget Tracking Software

It is a given that project management involves budget tracking. There are a variety of tools and software for tracking a budget. Whatever is used, be sure the software makes sense to you. Ask others experienced in the software for support.

If the company standard software doesn't seem to apply to the program, or doesn't give a clear budget status, you should customize it for your needs or use a secondary tool. Organizations often have project management software which can be applied to a program with some customization.

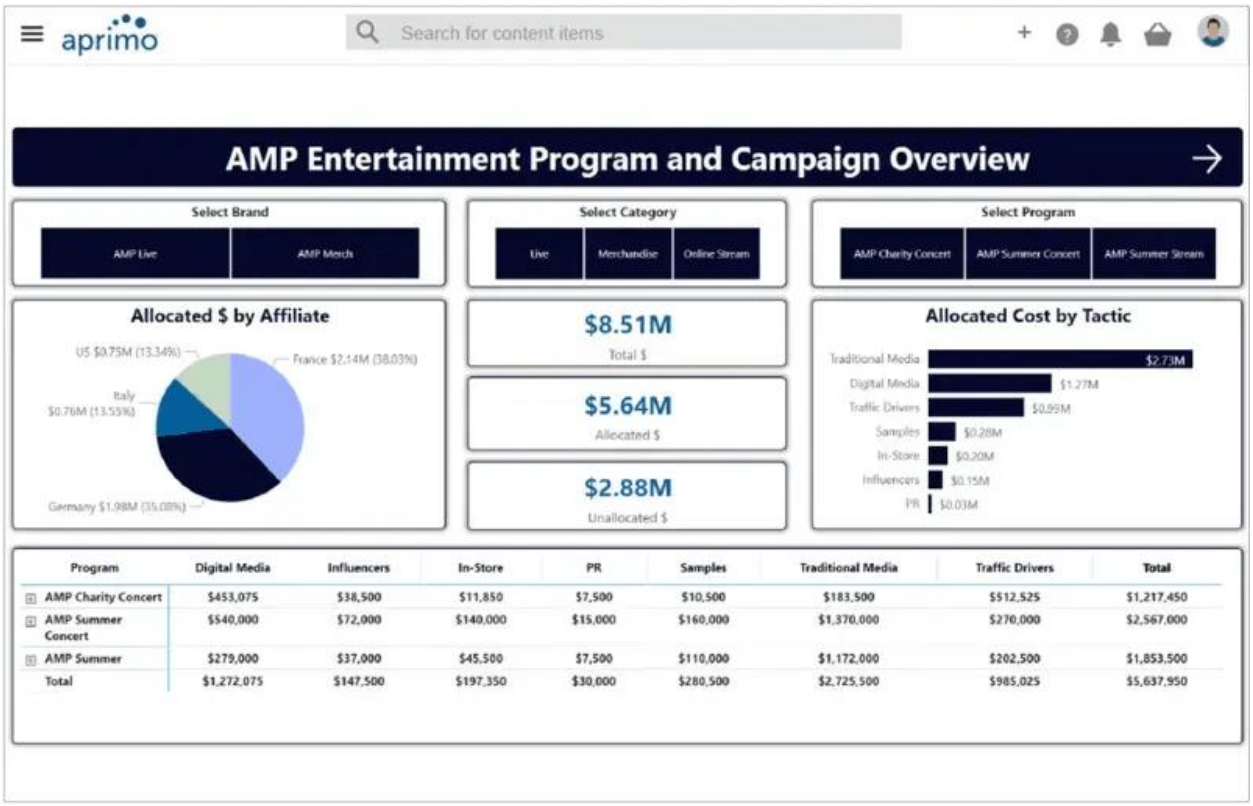


Figure 11: Example dashboard presenting budget status for multiple programs.
Source: https://www.aprimo.com/platform/plan-spend

Change Management

A “change” is a need to include something not identified in the agreed scope of work. For example, adding a feature to a design or addressing a new regulatory requirement. Addressing a quality review comment or fixing a mistake is not a “change” in this context since the scope of work doesn’t change.

Changes typically start at the project level and are addressed by both the project manager and the program manager. For example, it is realized that a forklift charging station needs to be added to the design for Project A, which is primarily addressed by the project manager for Project A. The program manager then coordinates for the other projects to also add a forklift charging station.

Some changes start at the program level are then applied to the projects as needed. For example, the project sponsor requests a change that impacts multiple projects. Or new technology is identified that should be integrated into the design of multiple projects.

It helps to be prepared for changes with a Change Management Plan. And then once a potential change is identified, procedures identified in the Change Management Plan can be quickly following to resolve the issue and move forward. A typical workflow for a potential change is as follows:

1. Potential change is identified
2. Cost and budget impact quantified
3. Change details/proposal presented to decision makers
4. Change approved
5. Budget and/or schedule revised
6. Change implemented
7. Change quality review
8. Lessons learned log updated

Change Log

A Change Log keeps track of changes and includes all the changes to the budget and schedule. Often there is a separate log for each project and one for the overall program.

See Table 9 for an overall program example. In this case, Program C is on the critical path for the program so schedule delays impact the overall program. Program A has 100 days of float, so the project delays don't change the program completion until those 100 days are used up.

Table 9: Example Program Change Log

Proposed Change No.	Agreed Change No.	Component / Project	Change Description	Cost Adder	Schedule Change (calendar days)		Status
					Project	Program	
PC1	N/A	Project A	Building 22 Expansion	$80,000	+80	+0	Denied
PC2	C1	Project C	New Separate Building	$100,000	+100	+100	Approved
PC3	C2	Project C	Add Cooling Redundancy	$20,000	+21	+21	Approved
PC4	TBD	Project A	Add Access Control to Doors	$10,000	+14	+0	Pending
PC5	TBD	Project C	Add Access Control to Doors	$10,000	+14	+14	Pending
PC6	TBD	New Component	Regulatory Changes Study	$20,000	+0	+0	Pending

Risk Management

One approach to preventing issues/problems is through Risk Management. Risks are potential events that would have a negative impact on the program/project. Risk Management involves these activities:

1. Identifying risks (risk assessment)
2. Preparing for risks (risk planning)
3. Responding to risks (risk mitigation)

The goal of risk management is to minimize the impact of risks in order to keep on track to achieving program goals and performance criteria. An initial risk assessment and risk planning is done in the Program Definition phase, when periodic re-assessments throughout the program.

Risk Assessment

An initial risk assessment is done in the Program Definition phase.

Risk Register

A risk register is a table with a list of identified risks. Normally, there are columns for risk description, probability (aka likelihood), cost & schedule impact (aka severity or consequence), priority (aka rank), mitigation strategy, response, and status. See Table 10 for an example.

Table 10: Example Program Risk Register

Risk No.	Component / Project	Risk Description	Likelihood	Cost Impact	Schedule Impact	Mitigation Strategy	Status
1	Project B	Add parking spaces due to building occupancy change	High	$100,000	12 weeks	Apply for zoning variance	Active
2	Entire Program	Operations staff change and new review comments provided	Medium	$50,000	4 weeks	Document and finalize review comments	Active
3	Projects A & B	Key electrical engineer no longer available	Medium	$20,000	4 weeks	Gain written commitment	Mitigated

Risk Scoring

One way to prioritize risks is to assess the severity (cost and schedule impact) and likelihood (aka probability) of each risk. See Figure 12 for a plot of severity versus likelihood with resulting risk scores from 1 to 12. This is called a risk matrix.

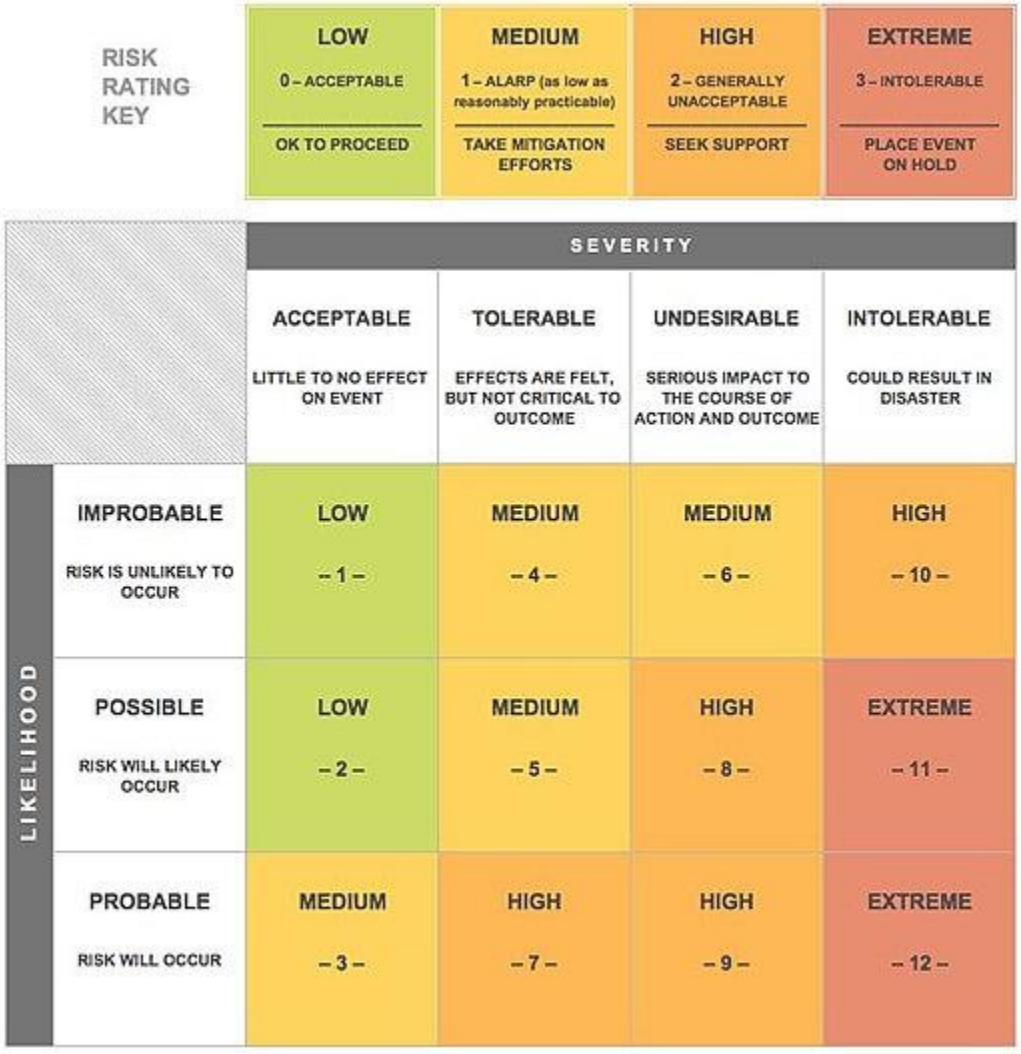


Figure 12: Risk assessment matrix with “severity” resulting in higher scoring.
Source: commons.wikimedia.org/wiki/File:IC-Risk-Assessment-Matrix-Template.jpg, U3115299, CC-BY-SA-4.0

Another approach for risk scoring is to sum the severity and likelihood values (each on the same scale), per this formula:

Risk Score = IF * Severity Score + Likelihood Score
where IF = Importance factor (often 1.5 to 2.5)

Note that a lower score is less risk.

Risk Ranking

After each risk is given a score on the risk register, the risks can be arranged by score from highest to lowest, so most important risks are addressed first. The process of scoring and sorting risks is known as risk ranking.

Risk Mitigation Planning

Once risks have been identified, logged, and quantified, the next step is to plan ways to avoid the risks (if possible) and mitigate the risks (minimize negative impacts). Mitigation plans and options should be added to the risk register.

Risk Delegation

Staff assignments can are also added to the risk register, so each risk has someone responsible for managing the risk. Staff should be informed of their assigned risks. For items specific to one project, the project manager can be assigned, and they can delegate to a project team member if applicable.

Inspire the Team

The program manager should inspire the team to accomplish the program goals. The following are specific tasks that can make a big difference in leading the team to success:

- Create a positive vision for the program:
  - Identify inspirational aspects of the program. For example, new technologies, new software, sustainability, positive environment impact, social impact, popular products, interesting location, first of its kind improvements, major challenges to overcome, futuristic approach, etc.
  - How will the improvements make a difference in the lives of others?
  - Find impactful ways to share the inspirational aspects of the program
  - Envision success for the project, both internally and externally
  - Consider social media posts or stories on the program
- Foster team identity:
  - Create a program logo
  - Create a fun motto or saying
  - Social events
  - Team building exercises
- Early commitments:
  - During the Program Definition phase, inform key team members of the potential program including estimated budget and duration
  - Request budget and schedule commitment from staff
  - If a verbal commitment is given, document it with an email
- Regular updates on project status:
  - Team members will be more engaged if they know the program status
  - Consider bi-weekly or monthly status updates by meetings or emails
  - Updates should include key accomplishments, budget status, schedule status, and any changes
- Recognize outstanding work:
  - Find ways to recognize individuals who are performing well or have achieved something exciting
  - Options include words of gratitude, public recognition, bonus payment, award plaque or certificate, group celebration, and informing their supervisor

- Individual and Group Communication
  - Regular group meetings with project managers, portfolio director, program sponsor, etc.
  - Regular and unplanned individual meetings with project managers
  - Listen to the needs of team members and stakeholders
  - Help resolve conflicts and mitigate personality clashes
- Sharing Information
  - Ensure team members have access to program documents
  - Periodically review the network folder structure, file names, and contents
  - Point out key document locations to team members
  - Confirm with project managers that they have access to and have reviewed all program documentation
- Motivate and Empower the Team
  - Be engaging and encourage the team to achieve great things
  - Put in the effort to ensure everyone is clear on upcoming tasks and have the information they need
  - Overcommunicate when needed as a precaution
  - Respect and empower the project manager as the leader of their project and project team; avoid micro-management
  - Be a transformational leader, as shown in Figure 13

Figure 13: The Full Range Leadership Model. The goal is for a leader to put regular effort into motivating and empowering the team in order to maximize engagement.
Source: Public Domain

Capital Improvement Programs

Public and private organizations with a lot of infrastructure often have a capital improvement program (CIP). The goal of such program is to systematically plan and execute projects that maintain and upgrade physical infrastructure to better meet current needs and future goals. There is typically an ongoing stream of projects with no program closure in sight.

CIPs are often managed as portfolios since the projects often have little relation to one another. Within a CIP "portfolio", there may be programs (or sub-programs) such as water, wastewater, stormwater, reuse, pipelines, pump stations, treatment systems, etc. These programs have annual budgets and are managed like an ongoing program that is always in the Delivery Phase. There is a CIP planning process to add new projects to the program(s).

CIP Planning

A CIP needs to undergo regular planning to assess the budget, assess the schedule, modify program goals, and identify new projects. Often CIP planning is done once a year and documented in an annual report and an updated Master Plan.

The following are common steps in CIP planning:

- Review program budget and schedule status
- Review condition assessments
- Review performance assessments
- Review risk assessments and risk registers
- Review and update the Master Plan
- Make new project selections
- Create annual report

Master Plan

A Master Plan is a technical engineering document intended to guide decisions infrastructure improvements. A Master Plan often include the following: summarize existing infrastructure including condition and performance assessment results, forecasts future demands, identifies potential improvement projects, compares alternatives, estimates costs at a high-level, provides recommendations on improvements and priorities.

Often a Master Plan is created every 3 to 5 years. To keep it relevant, it is helpful to make updates or amendments each year.

Project Selections

The following are suggested steps for project selection:

1. Create a table of potential projects and motivations (see Table 11),
2. Sum the number of motivations (also called drivers) for each potential project (greater = high priority),
3. Estimate the cost for each potential project (often in Master Plan),
4. Compare total cost to program budget available,
5. Decide on projects to proceed based on motivations, costs, and program budget,
6. Schedule out projects based on resources and budgets,
7. Present to and obtain approval from decision makers.

In Table 11, the last two columns “No. of Motivations” and “Cost per Motivation” can be used to help select projects for proceeding. Projects with the most motivations and with the lowest cost per motivation are highlighted **red**. Some motivations such as regulatory requirements may necessitate selecting projects with higher cost and fewer motivations.

Potential projects that cost more than the available program budget have the following options:

1. Split into multiple smaller projects and advance only the first project/phase.
2. Excess budget can be passed to the next year and combined with that year’s budget to give enough funding for the project.
3. One or more active projects can be paused/delayed to free up funding.
4. Budget can be transferred from another program with justification and approval.
5. Budget can be increased with justification and approval.

Table 11: Example CIP Project Planning Table

ID No.	Potential Project Name	Cost Estimate ($M)	New Develop-ment	Climate Change	Water Reuse	Effluent Water Quality	Remaining Useful Life	High Risk Ranking	Redund-ancy	Qualifies for Funding	Regulatory Needs	Other	No. of Motivations	Cost per Motivation
1	Influent Pump Station Expansion	$3.0	X						X				2	$1.5
2	Grit Removal Rehabilitation	$1.2					X	X					2	$0.6
3	Aeration Basin Rehabilitation	$0.8					X	X				Safety Improvement	3	$0.3
4	Clarifier Mechanism Replacement	$0.6				X		X					2	$0.3
5	Plant Water Reuse System	$1.0			X					X			2	$0.5
6	Yard Piping Rehabilitation	$0.8					X	X					2	$0.4
7	Transfer Pump Station Replacement	$1.8	X				X	X	X				**4**	$0.5
8	Selector Tank Addition	$2.1	X			X					X		3	$0.7
9	Phosphorus Removal Addition	$3.0				X				X	X		3	$1.0
10	New Chemical Building	$2.2	X	X				X			X	City Council Agenda Item	**5**	$0.4
11	Flood Protection Improvements	$1.5		X						X		City Council Agenda Item	3	$0.5
12	Isolation Valve Additions	$0.4							X			Correct Lack of Isolation	2	**$0.2**
13	Instrumentation Upgrades	$0.3				X		X				Highest COF	3	**$0.1**
14	Actuated Valve Replacements	$0.6					X	X					2	$0.3
	Total ($M)	$19.3	$9.1	$3.7	$1.0	$6.0	$5.2	$8.3	$5.2	$5.5	$7.3	$5.2	-	-

Example Problem 8

Program Manager Pat helped prepare Table 11 and now needs help to select which projects to proceed, while staying within a program budget range of $4.0M to $4.5M. The goal is to proceed with the greatest number of projects that are highlighted **red** in the last two columns. Help Pat decide which project(s) should be eliminated and what is the total cost?

Solution:

The projects highlighted **red** are as follows:

- $1.8M – 7, Transfer Pump Station Replacement, 4 motivations
- $2.2M – 10, New Chemical Building, 5 motivations
- $0.4M – 12, Isolation Valve Additions, $0.2M per motivation
- $0.3M – 13, Instrumentation Upgrades, $0.1M per motivation

  $4.7M – Total

The total exceeds the $4.5M budget by $0.2M. The following are options for proceeding:

1. Eliminate Project No. 12 to save $0.4M for total $4.3M.
2. Eliminate Project No. 13 to save $0.3M for total $4.4M.

In comparing options 1 and 2, Project No. 13 has a greater number of motivations (3 versus 2) and a lower cost per motivation ($0.1M versus $0.2M). Therefore, Project No. 13 is a better choice to proceed based on information available.

Recommendation is to eliminate Project No. 12 and proceed with the following projects for a total cost of $4.3M:

- $1.8M – 7, Transfer Pump Station Replacement, 4 motivations
- $2.2M – 10, New Chemical Building, 5 motivations
- $0.3M – 13, Instrumentation Upgrades, $0.1M per motivation

  $4.3M – Total

Helpful References

AXELOS (2020) “MSP (Managing Successful Programmes)”, 5th Ed. https://www.axelos.com/certifications/propath/msp-programme-management

Eby, K (2022) “The Essential Guide to Creating a Program Management Plan” https://www.smartsheet.com/content/program-management-plan

EPA (2007) “Asset Management: A Best Practices Guide”. EPA-816-F-08-014.

Lessard C; Lessard J (2007) “Project Management for Engineering Design”. Morgan and Claypool Publishers.

Oberlender, G.D. (2022) “Project Management for Engineering and Construction: A Life-Cycle Approach”. McGraw Hill, 4th Ed.

PMAJ (2017) “A Guidebook of Program & Project Management for Enterprise Innovation”. International Ed. Project Management Association of Japan.

Project Management Institute (2021) “A Guide to the Project Management Body of Knowledge (PMBOK)”. 7th Ed.

Project Management Institute (2024) “The Standard for Program Management”. 5th Ed.

PSMJ Resources, Inc. “The A/E/C Project Management Bootcamp Workbook”. https://www.psmj.com/PMBCbonustools .

Smith, N.J. (2007) “Engineering Project Management”. Wiley-Blackwell; 3rd Ed.

Stobierski, T (2020) “How to Calculate ROI to Justify a Project”. https://online.hbs.edu/blog/post/how-to-calculate-roi-for-a-project

Thiry, M (2016) “An Integrated Program Life Cycle” https://www.linkedin.com/pulse/integrated-program-life-cycle-part-one-michel-thiry/

